



**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**  
**NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY**  
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OFFICE OF  
AIR AND RADIATION

March 4, 2004

CCD-04-08 (LDV/LDT/MDPV/HDV)

Dear Manufacturer:

**Subject:** Environmental Research Consortium Request for Use of EPA 2007 Heavy-Duty Engine Particulate Matter Sampling Procedures for Light-Duty Vehicles

Based on a review of the attached Environmental Research Consortium (ERC) petition and following consultation with EPA staff from the Laboratory Operations Division (LOD) and the Assessment and Standards Division (ASD), EPA is approving the optional use of heavy-duty particulate matter (PM) sampling and measurement techniques for use in light-duty vehicle testing. These sampling and measurement techniques apply to light duty vehicles operated on gaseous and petroleum based fuels. This approval is granted pursuant to CFR 86.106-96(a) which permits use of alternate equipment, procedures, and calculation methods which yield equivalent or superior results and if approved in advance by the Administrator.

**Background**

In early January, 2004, EPA received a petition from ERC, whose members include DaimlerChrysler, Ford, and GM. The petition was addressed to Merrylin Zaw-Mon, Director of the Certification and Compliance Division and requested permission to use 2007 MY heavy-duty engine particulate measurement methods for optional use in light-duty vehicle particulate measurement.

Members of LOD and ASD have been active participants along with ERC members in the development of revised heavy-duty particulate sampling procedures.

On January 29, 2004 the California Air Resources Board issued a conditional approval of the ERC petition, based on final approval from EPA.

**Review of ERC Petition**

The model year 2007 heavy-duty PM measurement procedures, which both EPA and ERC believe are also appropriate for light duty diesel vehicles, are summarized in a memo from Matt Spears of the EPA Assessment and Standards Division in the Office of Transportation and Air Quality. This memo is in Air Docket A-99-06 IV-B-11 of the 2007 heavy-duty rulemaking and is included as Attachment 1 to the ERC petition. Attachment 2 is a copy of CFR sections 86.1310-2007 and 86.1312-2007 which describe the heavy-duty engine particulate sampling system.

Attachment 2 highlights those paragraphs of 86.1310-2007 which do not apply to light duty vehicle testing. They include: paragraphs (a)(1), (b)(2), (b)(3), and (b)(5). Paragraph (a)(1) mentions use of a subsonic venturi while paragraphs (b)(2), (b)(3), and (b)(5) all describe heavy duty emission measurement requirements for HC, CO, CO<sub>2</sub>, and NO<sub>x</sub> which employ heated and/or continuous sampling requirements which differ from light-duty vehicle sampling and analysis techniques. EPA agrees that these paragraphs do not apply, because they are inconsistent with exhaust emission measurement requirements for light-duty vehicles.

CCD is approving this petition because the revised heavy duty particulate sampling equipment and procedures provide the most technically up to date, accurate, and repeatable methodology for measuring the very low levels of particulate from current and future light duty vehicles.

Some of the specific advantages of the heavy duty sampling methods as they may apply to light duty vehicle sampling include:

- Allowance of secondary dilution of the exhaust sample to comply with filter zone temperature requirements while maintaining gaseous emission concentrations well above the limits of detection of the analyzers.
- Specifications for dilution air filtration to minimize the effects of variability in background air.
- Standardization of filter cartridge and holder design to reduce test to test variability based on proven success of ambient monitor sampling designs.
- Standardization of filter probe diameter to provide more uniform probe design, thereby reducing site-to-site test variability.
- Specification of a new filter face temperature to reduce variability by limiting temperature effects on semi-volatile particulate matter.
- Addition of a particle pre-classifier to remove extraneous mechanically generated particles not formed during the combustion process.
- High efficiency sample filter specifications will reduce lot to lot variability of filters.
- Many new specifications for the filter weighing room and microbalance, all designed to improve filter weighing accuracy and repeatability.
- Recommendation of Class 1000 clean room conditions to reduce variability resulting from airborne particulate matter.

#### **Future NVFEL PM Measurement Capabilities**

EPA's new particulate sampling system which will be installed in NVFEL Room 329 will

employ the particulate sampling concepts described in the ERC petition, with one minor exception to the specifications described in 86.1310-2007(b)(6)(vi). In this section, the requirement that the filter holder assembly shall be located within 12 inches (30.5 cm) of the exit of the secondary dilution tunnel will be modified by amendment to specify that the particulate sample media be located within 50 cm downstream of the exit of the preclassifier. EPA intends to revise this regulation accordingly in the near future.

If you have questions concerning this guidance letter, please contact Martin Reineman 734-214-4430.

Sincerely,

A handwritten signature in black ink, appearing to read "Merrylin Zaw-Mon".

Merrylin Zaw-Mon, Director  
Certification and Compliance Division  
Office of Transportation and Air Quality

Attachments

DAIMLERCHRYSLER



GM Powertrain

Date: November 25, 2003

To: Ms. Merrylin Zaw-Mon  
Director, Certification & Compliance Division  
Office of Transportation and Air Quality  
US Environmental Protection Agency  
Mail Code: 6403J  
1200 Pennsylvania Avenue, N.W.  
Washington, D.C. 20460

Cc: Mr. Mike Sabourin  
Director, Laboratory Operations Division  
Office of Transportation and Air Quality  
2565 Plymouth Road  
Ann Arbor, MI 48105

Mr. Matt Spears  
Assessment & Standards Division  
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US Environmental Protection Agency  
Mail Code: ASD1  
2000 Traverwood Dr  
Ann Arbor, MI 48105

Subject: Particulate Measurement for Light-Duty Vehicles

We, as light-duty vehicle manufacturers, respectfully request EPA approval for the optional use of the PM measurement procedures published as part of the recent EPA final rule, effective model year 2007 for heavy-duty diesel engines (Federal Register, Rules and Regulations, Vol. 66, No. 12, Thursday, January 18, 2001). Pursuant to EPA approval, these procedures could be used in lieu of the currently specified PM measurement procedures for light-duty vehicles. This request would allow light-duty vehicle manufacturers to continue to use the current light-duty PM measurement procedures or to use the heavy-duty diesel engine PM measurement procedures. 40 CFR 86.1840-01 allows for use of alternative procedures when specified procedures do not allow for satisfactory testing, with prior Administrator approval.

We are making this request because the heavy-duty diesel rule specifies the most technically updated PM test procedures, and we feel this is especially important because of the very low

levels of PM that we are now measuring. There are several reasons why we believe these PM measurement procedures should be adopted for light-duty vehicles. Most of these reasons are already summarized in a memo to Air Docket A-99-06, number IV-B-11, entitled, "Description of Changes to the Test Procedures Specified in 40 CFR Part 86 for Model Year 2007 and Later Heavy-Duty Engines." This memo was authored by Matt Spears at U.S. EPA, and this docket is enclosed for your reference.

There are additional reasons for our request that are specific to new requirements in light-duty vehicle testing. For example, the currently prescribed single stage dilution particulate sample zone temperature can not exceed 52°C (125°F), as stated in the CFR section 86.110-94 (b)(1) and (2). With the implementation of the light-duty vehicle US06 test requirements, this sample zone temperature requirement is difficult to achieve without increasing the CFV bulk stream flow to very large values. Diesel particulate trap technology also causes this sample zone temperature to be exceeded. When the CFV bulk stream flow is increased to around 2000 scfm, to lower the sample zone temperature to an acceptable level, the measured concentrations of HC, CO, NO<sub>x</sub> and CO<sub>2</sub> become exceedingly small. These small concentrations result in diminished measurement accuracies for the gaseous exhaust constituents. Therefore, we feel that increasing the bulk stream flow is not the correct solution to measure exhaust emissions accurately. The solution finalized in the heavy-duty test procedures specifies secondary dilution of the particulate measurement flow stream. This technique allows for the measurement of HC, CO, NO<sub>x</sub> and CO<sub>2</sub> at lower bulk stream flows, while also providing filter face temperature control for PM measurement, therefore maintaining better measurement accuracies for all constituents. And to improve the weighing accuracy of the particulate on the filter, EPA also specified in the heavy-duty test procedures tighter weighing room environmental controls and a more accurate weighing scale.

We specifically request that §86.1310-2007 be approved for light-duty PM measurement procedures, and if light-duty manufacturers choose to use §86.1310-2007, then §86.1312-2007 must be used in its entirety.

However, we request to omit the following paragraphs from our request for approval: §86.1310-2007 paragraphs (a), b(2), b(3), b(5) and the mention in b(1)(ii) of the allowance for subsonic venturis. There are specific reasons to omit these paragraphs. Paragraphs b(2) and b(3) refer to heated HC measurement, and paragraph b(5) refers to continuously integrated NO<sub>x</sub>, CO, and CO<sub>2</sub> measurement, and these are not consistent with prescribed light-duty measurement procedures for these constituents. A portion of paragraph b(1)(ii) refers to subsonic venturis, which currently are not allowed for light-duty vehicle testing. And paragraph (a) mentions each of the above items, and this paragraph is not required for conducting PM measurement procedures.

We are submitting an edited version of §86.1310-2007 and the entire §86.1312-2007 to clarify the exact text that we are requesting for approval.

Note that the proposed paragraphs to be *omitted* are marked in yellow.

Respectfully Submitted,

Encl.

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Reginald R. Modlin  
Director,  
Regulatory Affairs,  
DaimlerChrysler

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David Kulp  
Manager,  
Certification Engineering,  
Ford Motor Company

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Randy Harvey  
Manager, Compliance  
Planning and Integration,  
General Motors

December 6, 2000

Memorandum

From: Matthew W. Spears  
Office of Transportation Air Quality

To: Air Docket A-99-06, IV-B-11

Subject: Description of Changes to the Test Procedures Specified in 40 CFR Part 86 for Model Year 2007 and Later Heavy-Duty Engines

This document explains the reasons for changes being made to 40 CFR Part 86 Subpart N. These modified test procedures are applicable to FTP and the steady state testing conducted under 40 CFR Part 86 Subpart N. These changes are being made as part of the final rulemaking for model year 2007 and later heavy-duty diesel engines. Because emission standards are being lowered by more than 90% as part of this rule, measurement procedures are being revised to ensure that test facilities will be able to adequately measure emissions below the levels of the new standards. These new test procedures are intended to reduce measurement variability to a level that will maintain the same percent of measurement accuracy as the current standards, and therefore have the same impact on the effective stringency of the new standards. In this rulemaking, the Environmental Protection Agency is also clarifying the application process for Administrator approval of alternate test procedures. This is being done so that the EPA will be better able to respond to emerging technologies that might simplify emissions test in the future.

**§86.1306-07 Equipment required and specifications: overview.**

The use of the new test procedures will be allowed prior to 2007. Because all the new test procedures were selected to reduce variability without effecting stringency as compared with testing accuracy against current standards, EPA sees no reason why test facilities cannot begin making changes immediately as long as good engineering judgement is followed. For example, good engineering judgement may prevent a manufacturer from adopting certain portions of the new procedure without adopting other portions at the same time. EPA has analyzed these changes collectively, rather than individually. Thus, it may or may not be appropriate to selectively adopt some of these changes without others before 2007.

Use of old test procedures in 2007 and beyond must be approved by the Administrator. This allows temporary exemptions on case- by- case basis.

Approval of alternate test systems is specified in this section. It outlines four required sections of any application:

1. A theoretical explanation of the alternate system's measurement techniques, and why the alternative technique should provide equivalent results as compared to the specified technique.
2. A detailed description of the alternate system hardware and software.
3. A detailed description of the alternate system calibration, operation and maintenance procedures.
4. A statistical comparison of experimental results between the alternate system and the specified system.

This information is being added so that instrument manufacturers would know specifically on what merits EPA would approve an alternate system.

**§1310-07 Exhaust gas sampling and analytical system for gaseous emission from heavy-duty diesel fueled engines and particulate emissions from all engines.**

A provision to allow multiple sampling systems is being added. This provision enables the use of statistics to reduce the effects of random error on test results.

A provision to allow the use of a sub-sonic venturi to measure total flow of a constant volume sampling system is being added. This provision enables the use of a more flexible flow measurement allowing optimum adjustment of overall dilution ratio. This technique is often used to calibrate the previously specified critical flow venturi and positive displacement pump techniques.

The provision for single dilution PM measurement is being removed. The new filter face temperature specification ( $47^{\circ}\text{C} \pm 5^{\circ}\text{C}$ ) makes single dilution virtually impossible without significant heat transfer, which would otherwise lead to increased variability in the PM results due to thermophoretic PM loss and eventual re-entrainment.

The new filter face temperature specification of  $47^{\circ}\text{C} \pm 5^{\circ}\text{C}$  reduces PM variability by limiting temperature effects on semi-volatile material phase distribution between the particulate and gas phases.

Dilution air minimum temperature is being lowered to  $15^{\circ}\text{C}$ . This provision allows for lower dilution ratios while maintaining temperature requirements. This increases dilute emissions concentrations, which in turn reduces variability when analyzers are operated near their minimum detection limits.

Bag sampling specifications are being added to allow the use of mechanical integration of the sample. This allows for the use of highly sensitive analyzers that typically do not have the response time that is required for continuous integration.



Dilution air filtration specifications are being added. This provision reduces variability by minimizing the background filter correction. Without filtration, subtraction between 2 large numbers would increase variability in the PM results.

Particulate probe minimum diameter is being decreased to allow for standard tubing sizes. This allows for a more uniform probe design, which decreases site-to-site variability.

Maximum gaseous measurement system response requirement is being decreased from 20 to 10 seconds. This provision reduces system residence time, which would otherwise lead to variability due to diffusion mixing, loss and re-entrainment.

Recommendation for a low thermal capacity dilution tunnel and particulate sampling system is being added. Low thermal capacity reduces temperature gradients, which would otherwise lead to solid and semi-volatile loss and re-entrainment, which ultimately would lead to increased variability.

High efficiency sample filter specifications are being established. This provision eliminates the lot-to-lot variability of the low-efficiency filters that were previously specified.

A smaller filter diameter was specified. The new diameter enables the use of the highly sensitive microbalances that could not be used with the previously specified filter diameter.

Filter cartridges and holders are being specified similar to EPA ambient regulations. Current Procedures do not specify filter holder design, and some of the current designs increase Variability because they can randomly remove material from the filter itself. The EPA Ambient regulations are based on significant research that explored the effects of filter holders and cartridge on sample flow loss. The provision to use this well-tested design eliminates the variability of different filter holders, and it prevents crushing and loss of filter material, which was known to occur in some holders.

A particle pre-classifier is being specified upstream of the PM filter. This provision reduces filter contamination by large mechanically generated particles that were not generated from engine combustion during the test.

**§86.1312-2007 Filter stabilization and microbalance workstation environmental conditions, microbalance specifications, and particulate matter filter handling and weighing procedures.**

Temperature and dew point specifications of the filter stabilization and microbalance environments are being made more stringent. The temperature specifications minimize Semi-volatile phase distribution variability, and maximize microbalance stability. Dew point specifications minimize water equilibration variability-especially when PM contains a significant fraction of sulfuric acid.

Recommendations for Class 1000 cleanroom conditions, as per Federal Standard 209D, were made in the filter stabilization environment. This specification limits the amount of allowable airborne particulate matter in a controlled environment. This provision illustrates the level of cleanliness required to minimize the likelihood of filter contamination during stabilization.

The new maximum allowable change in the reference filter weight will be 10 micrograms. This provision reduces the allowable level of filter contamination.

Microbalance performance and calibration specifications are being made more stringent. This provision requires the use of the most sensitive microbalances that are commercially available. This reduces measurement variability due to measuring near a less sensitive microbalance minimum detectable limit.

Recommendation for vibration, electrostatic, and draft isolation of the microbalance are being added. This provision provides guidance to minimize variability of the microbalance performance due to external effects.

Electrical grounding of the microbalance operator will be required. This reduces electrostatic variability, which is a well-known problem in weighing at the microgram level.

Electrostatic neutralizer specifications are being added. This provision ensures that there is adequate electrostatic neutralization, which reduces weighing variability.

Buoyancy correction calculations will be required. At the microgram level of weighing, variations in filter buoyancy in air can lead to undesirable variability.

Provisions for repeat weighing of the same filter are being added. This allows for the use of statistics to minimize the effect of random error on the test results.

#### **§86.1323-07 Oxides of nitrogen analyzer calibration**

More stringent calibration provisions are being specified for NO<sub>x</sub> analyzers. This reduces variability when an analyzer is measuring values near its minimum detection limit.

A combines water vapor and CO<sub>2</sub> quench check is being added. This provision restricts the use of analyzers that are susceptible to water vapor or CO<sub>2</sub> quench. This reduces error by eliminating one source of variability.

#### **§86.1334-07 Pre-test engine and dynamometer preparation**

A high temperature preconditioning cycle has been added prior to testing. The purpose of this cycle is to return the dilution and sampling systems to a repeatable state. This reduces variability due to contamination from a previous test.

#### **§86.1337-07 Engine dynamometer test run**

The requirement to detach the CVS from the engine exhaust during the soak period is being removed. This eliminates the possibility of contaminating the exhaust or dilution system, and it eliminates the possibility of introducing a leak in the middle of a test.

#### **§86.1338-07 Emission measurement accuracy**

Analyzer minimum detection limits are being defined in this section, and a procedure to independently determine minimum detection limits was specified. This provision allows for the use of an analyzer beyond its manufacturer specified minimum detection limit. This enables the measurement of extremely low levels of emissions with confidence.

Accuracy for bag and continuous analyzers are being specified with provisions to operate analyzers below their manufacturer specifications. This enables the measurement of extremely low levels of emissions with increased confidence.

**§ 86.1310-2007 Exhaust gas sampling and analytical system for gaseous emissions from heavy-duty diesel-fueled engines and particulate emissions from all engines.**

(a) General. The exhaust gas sampling system described in this paragraph is designed to measure the true mass of both gaseous and particulate emissions in the exhaust of heavy-duty diesel engines, and particulate emissions in the exhaust of all heavy-duty engines. (Gaseous emissions from non-petroleum-fueled diesel engines are measured using the system described in §86.1309.) This system utilizes the CVS concept (described in § 86.1309) of measuring the combined mass emissions of THC, NO<sub>x</sub>, CH<sub>4</sub> (if applicable) CO, CO<sub>2</sub> and particulate matter. For all emission measurement systems described in this section, multiple or redundant systems may be used during a single test. Statistical averages of data from multiple systems may be used to calculate test results, consistent with good engineering judgment. Weighted averages are allowed, where appropriate. Statistical outliers may be discarded, but all results must be reported. If the Administrator determines that the statistical analysis is not consistent with good engineering judgment, he/she may determine compliance from the arithmetic mean of the results. A continuously integrated system may be used for THC, NO<sub>x</sub>, CO and CO<sub>2</sub> measurement. The use of proportional bag sampling for sample integration is allowed for THC, NO<sub>x</sub>, CO, and CO<sub>2</sub> measurement, but requirements specific to bag sampling from diesel exhaust must be met for the THC and NO<sub>x</sub> emissions measurements. CH<sub>4</sub> measurement for calculation of NMHC (if applicable) is measured using GC-FID analysis of a proportional bag sample. The mass of gaseous emissions is determined from the sample concentration and total flow over the test period. The mass of particulate emissions is determined from a proportional mass sample collected on a filter and from the sample flow and total flow over the test period. As an option, the measurement of total fuel mass consumed over a cycle may be substituted for the exhaust measurement of CO<sub>2</sub>. General requirements are as follows:

(1) This sampling system requires the use of a CVS. The CVS system may use a PDP, SSV, or a CFV. PDP systems must use a heat exchanger. CFV systems may use either a heat exchanger or electronic flow compensation. When electronic flow compensation is used, the CFV may be replaced by a subsonic venturi (SSV) as long as the CVS concept as defined in §86.1309 is maintained (i.e., a constant volumetric flow-rate through the CVS is maintained for the duration of the test). Figure N07-1 is a schematic drawing of the CVS system.

(2) The THC analytical system for diesel engines requires a heated flame ionization detector (HFID) and heated sample system (191 ± 11 °C) using either:

(i) Continuously integrated measurement of diluted THC meeting the minimum requirements and technical specifications contained in paragraph(b)(3) of this section. Unless compensation for varying mass flow is made, a constant mass flow system must be used to ensure a proportional sample; or

(ii) Heated (191 ± 11 °C) proportional bag sampling systems for hydrocarbon measurement will be allowed if the bag sampling system meets the performance specifications for outgassing and permeability as defined in paragraph (b) (2) of this section.

(3) CH<sub>4</sub> measurement, if applicable, shall be conducted using a proportional bag sampling system with subsequent analysis using a gas chromatograph and FID. The CH<sub>4</sub> measurement

shall be done in accordance with SAE Recommended Practice J1151, "Methane Measurement Using Gas Chromatography" (1994 SAE Handbook, Volume 1: Materials, Fuels, Emissions, and Noise, Section 13, Page 13.170), which is incorporated by reference pursuant to § 86.1(b)(2). As an alternative, the manufacturer may choose one of the options set forth in § 86.004-28 (c) (8).

(4) [Reserved]

(5) [Reserved]

(6) The CO and CO<sub>2</sub> analytical system requires:

(i) Bag sampling (§ 86.1309) and analytical (§ 86.1311) capabilities, as shown in Figure N07-1; or

(ii) Continuously integrated measurement of diluted CO and CO<sub>2</sub> meeting the minimum requirements and technical specifications contained in paragraph (b)(5) of this section. Unless compensation for varying flow is made, a constant flow system must be used to ensure a proportional sample; and

(7) The NO<sub>x</sub> analytical system requires:

(i) Continuously integrated measurement of diluted NO<sub>x</sub> meeting the minimum requirements and technical specifications contained in paragraph (b)(5) of this section. Unless compensation for varying flow is made, a constant flow system must be used to ensure a proportional sample.

(ii) Bag sampling (§ 86.1309) and analytical (§ 86.1311) capabilities, as shown in Figure N07-1 (or Figure 07-2) will be allowed provided that sample gas temperature is maintained above the sample's aqueous dewpoint at all times during collection and analysis.

(8) The mass of particulate in the exhaust is determined via filtration. The particulate sampling system requires dilution of the exhaust to a temperature of  $47\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ , measured upstream of a single high-efficiency sample filter (as close to the filter as practical).

(9) Since various configurations can produce equivalent results, exact conformance with these drawings is not required. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the components of the system. Other components, such as snubbers, which are not needed to maintain accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgment.

(10) Other sampling and/or analytical systems may be used if approved as per §86.1306-07.

(b) Component description. The components necessary for exhaust sampling shall meet the following requirements:

(1) Exhaust dilution system. The CVS shall conform to all of the requirements listed for the exhaust gas CVS systems in § 86.1309(b), (c), and (d). With respect to PM measurement, the intent of this measurement procedure is to perform the sample cooling primarily via dilution and mixing with air rather than via heat transfer to the surfaces of the sampling system. In addition the CVS must conform to the following requirements:

(i) The flow capacity of the CVS must be sufficient to maintain the diluted exhaust stream at the temperatures required for the measurement of particulate and hydrocarbon emission noted below and at, or above, the temperatures where aqueous condensation in the exhaust gases could occur. This is achieved by the following method. The flow capacity of the CVS must be sufficient to maintain the diluted exhaust stream in the primary dilution tunnel at a temperature of  $191\text{ }^{\circ}\text{C}$  or

less at the sampling zone and as required to prevent condensation at any point in the dilution tunnel. Gaseous emission samples may be taken directly from this sampling point. An exhaust sample must then be taken at this point to be diluted a second time for use in determining particulate emissions. The secondary dilution system must provide sufficient secondary dilution air to maintain the double-diluted exhaust stream at a temperature of  $47\text{ C} \pm 5\text{ C}$ , measured at a well-mixed point located between 20 cm downstream of the filter face or 20 cm upstream of the filter face.

(ii) For the CVS, either a heat exchanger (i.e. CFV-CVS) or electronic flow compensation (i.e. EFC-CFV-CVS or EFC-SSV-CVS), which also includes the particulate sample flows is required. Refer to Figure N07-1.

(iii) When a heat exchanger is used, the gas mixture temperature, measured at a point immediately ahead of the critical flow venturi, shall be within  $\pm 11\text{ }^{\circ}\text{C}$  of the average operating temperature observed during the test with the simultaneous requirement that aqueous condensation does not occur. The temperature measuring system (sensors and readout) shall have an accuracy and precision of  $\pm 1.9\text{ }^{\circ}\text{C}$ . For systems utilizing a flow compensator to maintain proportional sampling, the requirement for maintaining constant temperature is not necessary.

(iv) The primary dilution air and secondary dilution air:

(A) Shall have a primary and secondary dilution air temperature equal to or greater than  $15\text{ }^{\circ}\text{C}$ .

(B) Primary dilution air shall be filtered at the dilution air inlet. The manufacturer of the primary dilution air filter shall state that the filter design has successfully achieved a minimum particle removal efficiency of 98% (less than 0.02 penetration) as determined using test method ASTM F 1471 - 93 (incorporated by reference at section 86.1). Secondary dilution air shall be filtered at the dilution air inlet using a high-efficiency particulate air filter (HEPA). The HEPA filter manufacturer shall state the HEPA filter design has successfully achieved a minimum particle removal efficiency of 99.97% (less than 0.0003 penetration) as determined using ASTM test method F 1471 - 93. It is recommended that the primary dilution air be filtered using a HEPA filter. EPA intends to utilize HEPA filters to condition primary dilution air in its test facilities. It is also recommended that charcoal hydrocarbon scrubbers not be used to precondition dilution air because these scrubbers may store and release adsorbed hydrocarbons in an unpredictable manner. It is acceptable to use a booster blower upstream or downstream of a HEPA filter in the primary dilution tunnel (and upstream of the introduction of engine exhaust into the CVS) to compensate for the additional pressure loss associated with the filter. The design of any booster blower located downstream of the filter should minimize the introduction of additional particulate matter into the CVS.

(C) Primary dilution air may be sampled to determine background particulate levels, which can then be subtracted from the values measured in the diluted exhaust stream. In the case of primary dilution air, the background particulate filter sample shall be taken immediately downstream of the dilution air filter and upstream of the engine exhaust flow (Figure N07-1). The provisions of paragraphs (b) (7) of this section, and of § 86.1312-2007 also apply to the measurement of background particulate matter, except that the filter temperature must be maintained below  $52^{\circ}\text{C}$ .

**(2) Heated proportional bag sampling systems.** If a heated ( $191 \pm 11\text{ }^{\circ}\text{C}$ ) proportional bag sampling system is used for THC measurement, sample bags must demonstrate minimal outgassing and permeability by passing the following performance test:

(i) Performance test for sample bag HC outgassing and CO<sub>2</sub> permeability. Bring the bag system to its operational temperature. Fill the heated sample bag with a nominal mixture of 1% CO<sub>2</sub> in N<sub>2</sub>. Perform an initial measurement of CO<sub>2</sub> and THC from the sample bag, and repeat the measurement after one hour. Acceptable performance criteria are < 2% decrease of the initial CO<sub>2</sub> reading and < 1 ppmC THC.

(ii) [Reserved]

(3) Continuous HC measurement system. (i) The continuous HC sample system (as shown in Figure N07-1) uses an "overflow" zero and span system. In this type of system, excess zero or span gas spills out of the probe when zero and span checks of the analyzer are made. The "overflow" system may also be used to calibrate the HC analyzer per § 86.1321(b), although this is not required.

(ii) No other analyzers may draw a sample from the continuous HC sample probe, line or system, unless a common sample pump is used for all analyzers and the sample line system design reflects good engineering practice.

(iii) The overflow gas flow rates into the sample line shall be at least 105% of the sample system flow rate.

(iv) The overflow gases shall enter the heated sample line as close as practicable to the outside surface of the CVS duct or dilution tunnel.

(v) The continuous HC sampling system shall consist of a probe (which must raise the sample to the specified temperature) and, where used, a sample transfer system (which must maintain the specified temperature). The continuous hydrocarbon sampling system (exclusive of the probe) shall:

(A) Maintain a wall temperature of  $191^{\circ}\text{C} \pm 11^{\circ}\text{C}$  as measured at every separately controlled heated component (i.e., filters, heated line sections), using permanent thermocouples located at each of the separate components.

(B) Have a wall temperature of  $191^{\circ}\text{C} \pm 11^{\circ}\text{C}$  over its entire length. The temperature of the system shall be demonstrated by profiling the thermal characteristics of the system at initial installation and after any major maintenance performed on the system. The temperature profile of the HC sampling system shall be demonstrated by inserting thermocouple wires (typically Teflon<sup>TM</sup> coated for ease of insertion) into the sampling system assembled in-situ where possible, using good engineering judgment. The wire should be inserted up to the HFID inlet. Stabilize the sampling system heaters at normal operating temperatures. Withdraw the wires in increments of 5 cm to 10 cm (2 inches to 4 inches) including all fittings. Record the stabilized temperature at each position. The system temperature will be monitored during testing at the locations and temperature described in § 86.1310-90(b)(3)(v)(A). (Note: It is understood that profiling of the sample line can be done under flowing conditions also as required with the probe. This test may be cumbersome if test facilities utilize long transfer lines and many fittings; therefore it is recommended that transfer lines be kept as short as possible and the use of fittings should be kept minimal.)

(C) Maintain a gas temperature of  $191^{\circ}\text{C} \pm 11^{\circ}\text{C}$  immediately before the heated filter and HFID. These gas temperatures will be determined by a temperature sensor located immediately upstream of each component.

(vi) The continuous hydrocarbon sampling probe shall:

- (A) Be defined as the first 25.4 cm (10in) to 76.2 cm (30 in) of the continuous hydrocarbon sampling system;
- (B) Have a 0.483 cm (0.19 in) minimum inside diameter;
- (C) Be installed in the primary dilution tunnel at a point where the dilution air and exhaust are well mixed (i.e., approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel);
- (D) Be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influence of any wakes or eddies; and
- (E) Increase the gas stream temperature to  $191^{\circ}\text{C} \pm 11^{\circ}\text{C}$  by the exit of the probe. The ability of the probe to accomplish this shall be demonstrated at typical sample flow rates using the insertion thermocouple technique at initial installation and after any major maintenance. Compliance with the temperature specification shall be demonstrated by monitoring during each test the temperature of either the gas stream or the wall of the sample probe at its terminus.
- (vii) The response time of the continuous measurement system shall be no greater than:
  - (A) 1.5 seconds from an instantaneous step change at the port entrance to the analyzer to within 90 percent of the step change;
  - (B) 10 seconds from an instantaneous step change at the entrance to the sample probe or overflow span gas port to within 90 percent of the step change. Analysis system response time shall be coordinated with CVS flow fluctuations and sampling time/test cycle offsets if necessary; and
  - (C) For the purpose of verification of response times, the step change shall be at least 60 percent of full-scale chart deflection.
- (4) Primary-dilution tunnel. (i) The primary dilution tunnel shall be:
  - (A) Small enough in diameter to cause turbulent flow (Reynolds Number greater than 4000) and of sufficient length to cause complete mixing of the exhaust and dilution air. Good engineering judgment shall dictate the use of mixing plates and mixing orifices to ensure a well-mixed sample. To verify mixing, EPA recommends flowing a tracer gas (i.e. propane or  $\text{CO}_2$ ) from the raw exhaust inlet of the dilution tunnel and measuring its concentration at several points along the axial plane at the sample probe. Tracer gas concentrations should remain nearly constant (i.e. within 2%) between all of these points.
  - (B) At least 8 inches (20 cm) in diameter.
  - (C) Constructed of electrically conductive material, which does not react with the exhaust components.
  - (D) Electrically grounded.
  - (E) EPA recommends that the tunnel should have minimal thermal capacitance such that the temperature of the walls tracks with the temperature of the diluted exhaust.
- (ii) The temperature of the diluted exhaust stream inside of the primary dilution tunnel shall be sufficient to prevent water condensation.
- (iii) The engine exhaust shall be directed downstream at the point where it is introduced into the primary dilution tunnel.
- (5) Continuously integrated  $\text{NO}_x$ , CO, and  $\text{CO}_2$  measurement systems. (i) The sample probe shall:



(A) Be in the same plane as the continuous HC probe, but shall be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influences of any wakes or eddies; and

(B) Heated and insulated over the entire length, to prevent water condensation, to a minimum temperature of 131°F (55 °C). Sample gas temperature immediately before the first filter in the system shall be at least 131 °F (55 °C).

(ii) The continuous NO<sub>x</sub>, CO, or CO<sub>2</sub> sampling and analysis system shall conform to the specifications of subpart D of this part, with the following exceptions:

(A) The system components required to be heated by subpart D need only be heated to prevent water condensation, the minimum component temperature shall be 131 °F (55 °C);

(B) The system response defined in § 86.329-79 shall be no greater than 10 seconds. Analysis system response time shall be coordinated with CVS flow fluctuations and sampling time/test cycle offsets, if necessary;

(C) Alternative NO<sub>x</sub> measurement techniques outlined in § 86.346-79 are not permitted for NO<sub>x</sub> measurement in this subpart;

(D) All analytical gases shall conform to the specifications of § 86.1314;

(E) Any range on a linear analyzer below 100 ppm shall have and use a calibration curve conforming to § 86.1323-07; and

(F) The measurement accuracy requirements are specified in § 86.1338-07.

(iii) The signal output of analyzers with non-linear calibration curves shall be converted to concentration values by the calibration curve(s) specified in subpart D of this part (§ 86.330-79) before flow correction (if used) and subsequent integration takes place.

(6) Particulate sampling system. This method collects a proportional sample from the primary tunnel, and then transfers this sample to a secondary dilution tunnel where the sample is further diluted. The double-diluted sample is then passed through the collection filter. Proportionality (i.e., mass flow ratio) between the primary tunnel flow rate and the sample flow rate must be maintained within ±5%, excluding the first 10 seconds of the test at start-up. The requirements for this system are:

(i) The particulate sample transfer tube shall be configured and installed so that:

(A) The inlet faces upstream in the primary dilution tunnel at a point where the primary dilution air and exhaust are well mixed.

(B) The particulate sample exits on the centerline of the secondary tunnel.

(ii) The entire particulate sample transfer tube shall be:

(A) Sufficiently distant (radially) from other sampling probes (in the primary dilution tunnel) so as to be free from the influence of any wakes or eddies produced by the other probes.

(B) 0.85 cm minimum inside diameter.

(C) No longer than 36 in (91 cm) from inlet plane to exit plane.

(D) Designed to minimize the diffusional and thermophoretic deposition of particulate matter during transfer (i.e., sample residence time in the transfer tube should be as short as possible, temperature gradients between the flow stream and the transfer tube wall should be minimized). Double-wall, thin-wall, air-gap insulated, or a controlled heated construction for the transfer tube is recommended.

(E) Constructed such that the surfaces exposed to the sample shall be an electrically conductive material, which does not react with the exhaust components, and this surface shall be electrically grounded so as to minimize electrostatic particulate matter deposition.

(iii) The secondary dilution air shall be at a temperature equal to or greater than 15 °C.

(iv) The secondary-dilution tunnel shall be constructed such that the surfaces exposed to the sample shall be an electrically conductive material, which does not react with the exhaust components, and this surface shall be electrically grounded so as to minimize electrostatic particulate deposition.

(v) Additional dilution air must be provided so as to maintain a sample temperature of  $47\text{ °C} \pm 5\text{ °C}$  upstream of the sample filter. Temperature shall be measured with a thermocouple with a 3/16" shank, having thermocouple wires with a gage diameter 24 AWG or smaller, a bare-wire butt-welded junction; or other suitable temperature measurement with an equivalent or faster time constant and an accuracy and precision of  $\pm 1.9\text{ °C}$ .

(vi) The filter holder assembly shall be located within 12.0 in (30.5 cm) of the exit of the inertial preclassifier.

(vii) The face velocity through the sample filter shall not exceed 100 cm/s (face velocity is defined as the standard volumetric sample flow rate (i.e., scm<sup>3</sup>/sec) divided by the sample filter stain area (i.e., cm<sup>2</sup>)).

(7) Particulate sampling. (i) Filter specifications. (A) Polytetrafluoroethylene (PTFE or Teflon<sup>TM</sup>) coated borosilicate glass fiber high-efficiency filters or polytetrafluoroethylene (PTFE or Teflon<sup>TM</sup>) high-efficiency membrane filters with an integral support ring of polymethylpentene (PMP) or equivalent inert material are required. Filters shall have a minimum clean filter efficiency of 99% as measured by the ASTM D2986-95a DOP test (incorporated by reference at section 86.1).

(B) Particulate filters must have a diameter of  $46.50 \pm 0.6\text{ mm}$  (38 mm minimum stain diameter).

(C) The dilute exhaust is simultaneously sampled by a single high-efficiency filter during the cold-start test and by a second high efficiency filter during the hot-start test.

(D) It is recommended that the filter loading should be maximized consistent with temperature requirements.

(ii) Filter holder assembly. The filter holder assembly shall comply with the specifications set forth for ambient PM measurement in 40 CFR 50 Appendix L 7.3.5, figures L-25 and L-26, with the following exceptions:

(A) The material shall be 300 series stainless steel instead of anodized aluminum.

(B) The 2.84 cm diameter entrance to the filter holder may be adapted, using sound engineering judgment and leak-free construction, to an inside diameter no smaller than 0.85 cm, maintaining the 12.5 ° angle from the inlet of the top filter holder to the area near the sealing surface of the top of the filter cartridge assembly. Figure N07-2 shows acceptable variation from the design in 40 CFR 50 Appendix L. Similar variations using sound engineering design are also acceptable provided that they provide even flow distribution across the filter media and a similar leak-free seal with the filter cartridge assembly.

(C) If additional or multiple filter cartridges are stored in a particulate sampler as part of an automatic sequential sampling capability, all such filter cartridges, unless they are installed in the

sample flow (with or without flow established) shall be covered or sealed to prevent communication of semi-volatile matter from filter to filter; contamination of the filters before and after sampling; or loss of volatile or semi-volatile particulate matter after sampling.

(iii) Filter cartridge assembly. The filter cartridge assembly shall comply with the specifications set forth for ambient PM measurement in 40 CFR 50 Appendix L 7.3.5, figures L-27, L-28, and L-29, with the following exceptions:

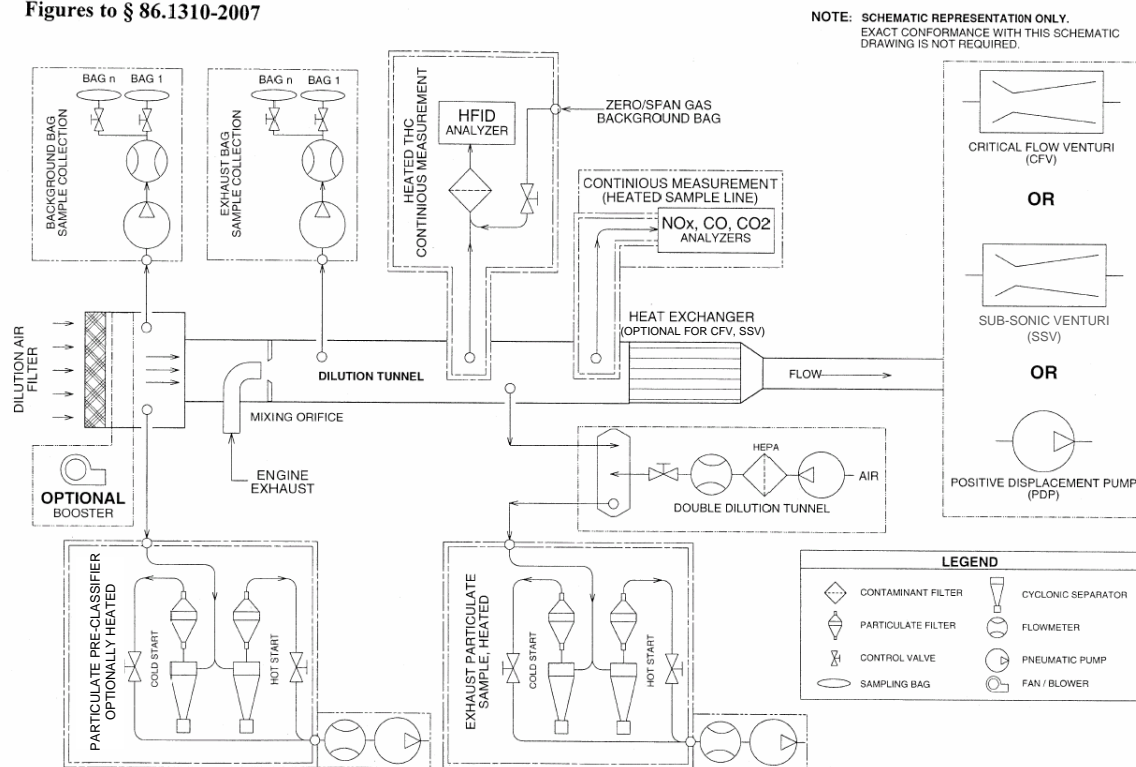
(A) In addition to the specified Delrin<sup>TM</sup> material, 300 series stainless steel, polycarbonate or acrylonitrile/butadiene/styrene (ABS) resin, conductive polypropylene or a combination of these materials may also be used.

(B) A bevel introduced on the inside diameter of the entrance to the filter cartridge, as used by some commercially available automated sequential particulate filter cartridge changers, is also acceptable (see Figure N07-3).

(iv) Particle preclassifier. A particle preclassifier shall be installed immediately upstream of the filter holder assembly (N07-1). A particle preclassifier may be used for an engine of model year earlier than 2007 only if the filters used in conjunction with the preclassifier comply with paragraph (i) of this subpart. The purpose of the preclassifier is to remove coarse, mechanically generated particles (e.g., rust from the engine exhaust system or carbon sheared from the sampling system walls) from the sample flow stream while allowing combustion-generated particles to pass through to the filter. The preclassifier may be either an inertial impactor or a cyclonic separator. The preclassifier manufacturer 50 % cutpoint particle diameter shall be between 2.5 µm and 10 µm at the volumetric flow rate selected for sampling of particulate matter emissions. Sharpness of cut is not specifically defined, but the preclassifier geometry shall allow at least 99% of the mass concentration of 1 µm particles to pass through the exit of the preclassifier to the filter at the volumetric flow rate selected for sampling particulate matter emissions. Periodic servicing of the preclassifier will be necessary to prevent a buildup of mechanically separated particles. The particle preclassifier may be made integral with the top of the filter holder assembly. The preclassifier may also be made integral with a mixing-tee for introduction of secondary dilution air, thus replacing the secondary dilution tunnel; provided that the preclassifier provides sufficient mixing.

## **Figures to § 86.1310-2007**

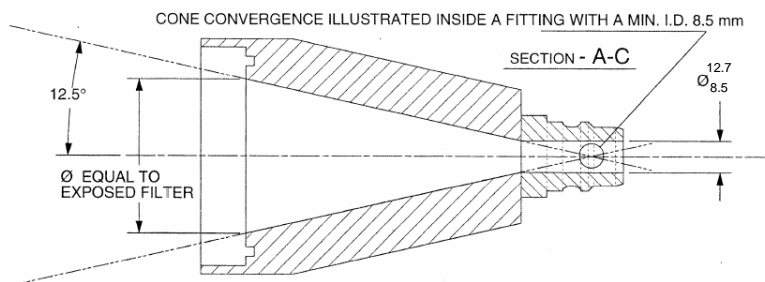
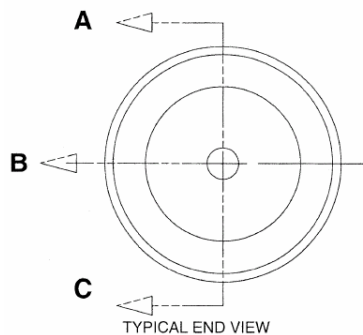
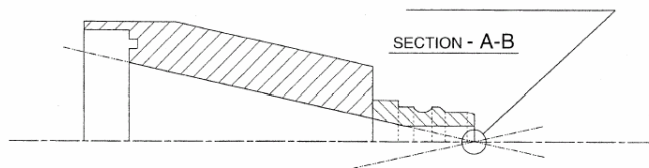
Figures to § 86.1310-2007



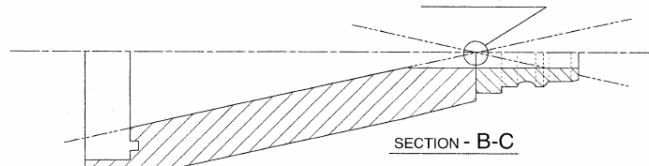
N07-1 GASEOUS AND PARTICULATE EMISSIONS SAMPLING SYSTEM (CONSTANT VOLUME SAMPLER – CVS)

**METRIC**  
mm

CONE CONVERGENCE ILLUSTRATED AT THE DOWNSTREAM END OF A FITTING WITH A MIN. I.D. 8.5 mm  
NOTE: THE FITTING IS MODIFIED TO MAINTAIN 12.5° TO THE CONVERGENCE .



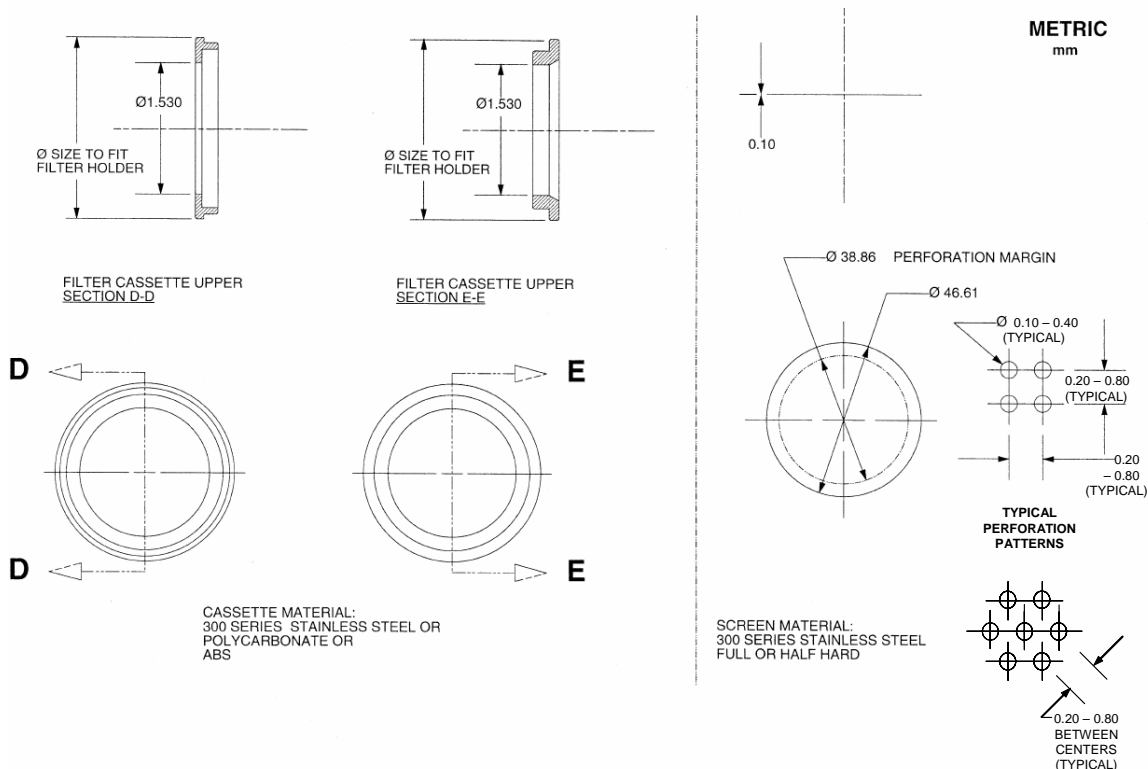
CONE CONVERGENCE ILLUSTRATED AT THE UPSTREAM END OF A FITTING WITH A MIN. I.D. 8.5 mm  
NOTE: THE FILTER HOLDER IS MODIFIED TO MAINTAIN 12.5° TO THE CONVERGENCE .



**NOTES:**

- 1) MATERIAL, 300-SERIES STAINLESS STEEL
- 2) ROUGHNESS, ALL WETTED SURFACES, 32 RMS
- 3) BREAK ALL SHARP EDGES

**N07-2 FILTER HOLDER GEOMETRY**



**N07-3 FILTER CASSETTE AND SCREEN**

**§ 86.1312\_2007 Filter stabilization and microbalance workstation environmental conditions, microbalance specifications, and particulate matter filter handling and weighing procedures.**

- (a) Ambient conditions for filter stabilization and weighing. (1) Temperature and humidity. (i) The filter stabilization environment shall be maintained at  $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$  and a dewpoint of  $9.5^{\circ}\text{C} \pm 1^{\circ}\text{C}$ . Dewpoint shall be measured with an instrument that exhibits an accuracy of at least  $\pm 0.25^{\circ}\text{C}$  NIST traceable as stated by the instrument manufacturer. Temperature shall be measured with an instrument that exhibits an accuracy of at least  $\pm 0.2^{\circ}\text{C}$  or better.
- (ii) The immediate microbalance workstation environment shall be maintained at  $22^{\circ}\text{C} \pm 1^{\circ}\text{C}$  and a dewpoint of  $9.5^{\circ}\text{C} \pm 1^{\circ}\text{C}$ . If the microbalance workstation environment freely circulates with the filter stabilization environment, and this entire environment meets  $22^{\circ}\text{C} \pm 1^{\circ}\text{C}$  and a dewpoint of  $9.5^{\circ}\text{C} \pm 1^{\circ}\text{C}$ , then there is no requirement to measure temperature and dewpoint at the microbalance separate from the filter stabilization location. Otherwise, temperature at the microbalance workstation shall be measured with an instrument that exhibits an accuracy of at least  $\pm 0.2^{\circ}\text{C}$  or better, and dewpoint shall be measured with an instrument that exhibits an accuracy of at least  $\pm 0.25^{\circ}\text{C}$  NIST traceable as stated by the instrument manufacturer.

(2) Cleanliness. (i) The microbalance and filter stabilization environments shall be free of ambient contaminants (such as dust or other aerosols) that could settle on the particulate filters. It is recommended that these environments be built to conform with the Class 1000 specification (or cleaner) as determined by Federal Standard 209D or 209E for clean room classification (Available from the Institute of Environmental Standards and Technology website at [www.iest.org](http://www.iest.org) or phone (847) 255-1561). An alternative recommendation would be to equilibrate and/or weigh the filters within a separate, smaller, particle-free, temperature and humidity-controlled chamber (i.e., "glove box").

(ii) Reference filters shall be used to monitor for gross particle contamination. It is required that at least two unused reference filters remain in the filter stabilization environment at all times in partially covered glass petri dishes, as in paragraph (c) (1) of this section. These reference filters shall be placed in the filter stabilization environment. The reference filters shall be weighed within 2 hours of, but preferably at the same time as, the sample filters. The reference filters shall be changed at least once a month, but never while any sample filters are between their tare weight (pre-sampling) and gross weight (post-sampling) measurements. The reference filters shall be the same size and material as the sample filters.

(3) Quality control of ambient conditions. (i) If, before the start of a weighing session, the temperature or dewpoint of the filter stabilization environment are not within specifications, then filters must remain in the environment for at least 30 minutes (60 minutes for engines of model year earlier than 2007) after conditions are corrected. If the filter stabilization environment changes during a weighing session such that the specifications are no longer met, the weighing session shall be suspended until the environment has returned to within specifications for at least 30 minutes (60 minutes for engines of model year earlier than 2007). Once the environment has returned to within specifications for at least 30 minutes (60 minutes for engines of model year earlier than 2007), the reference filters shall be reweighed and the criteria in paragraph (a)(3)(ii) of this section shall apply. Note that temperature and dewpoint shall be sampled once per second, and an unweighted 5-minute moving average of this data shall be calculated once per second. This moving average shall be used to determine the environment temperature and dewpoint for the purpose of determining whether or not the environment is within specifications.

(ii) If the average change in weight of the reference filters is more than 10 micrograms (after correcting for buoyancy as described in paragraph (c)(3) of this section), then all filters in the process of stabilization shall be discarded and all data collected with respect to the discarded filters shall be considered void. Note that more than 2 reference filters may be used to achieve a more robust average of the change in weight of the reference filters.

(b) Microbalance specifications. The microbalance used to determine the weights of all filters shall have a precision (standard deviation) of at least  $\pm 0.25$  micrograms or better for repeated weighing of a calibration weight, a precision of at least  $\pm 2.5$  micrograms or better for repeated weighing of a clean filter, and a readability equal to or less than 0.1 micrograms. It is recommended that the microbalance be installed on a vibration isolation platform to isolate the microbalance's load cell from external vibration. It is also recommended that the microbalance should be shielded from convective airflow by means of an electrically grounded static dissipative draft shield. Microbalance manufacturer specifications for all preventive

maintenance, periodic certification, calibration, and re-zeroing shall be followed. All certification and calibration procedures shall be NIST traceable, or traceable to an equivalent national standard.

(c) Particulate matter filter handling and weighing. Care should be taken to prevent contamination of the sample filters and to prevent a buildup of static charge on the filters that could interfere with filter weighing. Static neutralizers, such as Po-210 sources, shall be used to neutralize charge on a filter prior to each weighing. The static neutralizer must be grounded with respect to the microbalance. A static neutralizer should be replaced at the interval recommended by its manufacturer, or when it is no longer able to reduce static charge on a filter to less than  $\pm 2$  VDC as measured with an electrostatic monitor at the microbalance workstation. The person weighing filters shall be grounded with respect to the microbalance to prevent imparting a static charge on the filters. This can be accomplished safely by using a grounding strap such as the wrist straps that are commonly used in the microelectronics industry, or by connecting a similar grounding strap to the tweezers. To prevent electrical shock, a 1-megohm resistor should be installed in series between the person weighing filters and ground.

(1) Within the filter stabilization environment, a pair of clean and electrically conductive tweezers shall be used to place a filter in the lower half of a filter cassette and the cassette shall be placed in a partially open glass petri dish. The petri dish lid should extend over the filter to prevent gross contamination, but it should be left slightly open on one edge to permit stabilization with the environment for at least 30 minutes (60 minutes for engines of model year earlier than 2007).

(2) After at least 30 minutes (60 minutes for engines of model year earlier than 2007) of stabilization, each filter shall be weighed using the specified microbalance. The process of weighing a filter may be repeated and a statistical mean weight of a single filter may be calculated. Sound engineering judgment shall dictate the use of statistics to discard outliers and the weighting of averages. For a clean filter its single weight or statistical mean weight shall be considered the uncorrected tare weight of the filter.

(3) All filter weights shall be corrected for filter buoyancy in air. For the uncorrected tare weight of a filter, this calculated value is the corrected tare weight of the filter, and it must be recorded (see § 86.1344(e)(18)). Barometric pressure of the microbalance environment shall be measured with an instrument that exhibits  $\pm 0.01\%$  full-scale accuracy and 0.01% per-year full scale stability, and the full-scale value used for such a specification shall not exceed 200 kPa.



(i) Buoyancy correction calculation. (A) Calculate vapor pressure of liquid water using the dewpoint temperature in the Magnus formula:

$$P_w = 0.6113 \times 10^{((7.5 \times T_{dp})/(237.3+T_{dp}))}$$

Where:

$P_w$  = vapor pressure of liquid water, kPa.

$T_{dp}$  = dewpoint temperature, °C.

(B) Calculate air density using the ideal gas relationship and molecular weights of standard air and water:

$$A = (3.484 \times P - 1.317 \times P_w)/(T+273.15)$$

Where:

A = air density, kg/m<sup>3</sup>.

P = barometric pressure, kPa.

$P_w$  = vapor pressure of liquid water, kPa.

T = temperature, °C.

(C) Buoyancy correction:

$$M = R \times (1 - (A / \rho_w)) / (1 - (A / \rho_s)).$$

Where:

M = corrected mass in units of the balance display.

R = uncorrected filter weight in units of the balance display.

A = calculated air density, kg/m<sup>3</sup>.

$\rho_w$  = density of calibration weight used to calibrate the balance, kg/m<sup>3</sup>.

$\rho_s$  = density of filter material used to sample PM emissions, kg/m<sup>3</sup>.

(ii) For determining  $\rho_s$  note that PTFE (Teflon™) and borosilicate glass both have densities in the range of 2,200 to 2,400 kg/m<sup>3</sup>. Therefore, for PTFE-coated borosilicate glass fiber filters, an acceptable  $\rho_s$  is 2,300 kg/m<sup>3</sup>. Note also that polymethylpentene has a density of 850 kg/m<sup>3</sup>. Because Teflon PTFE membrane filters have an integral polymethylpentene support ring that accounts for 95% of the filter mass, an acceptable  $\rho_s$  for these filters is 920 kg/m<sup>3</sup>. Other  $\rho_s$  values for other filters may be obtained similarly.

Information about  $\rho_w$  should be available from the calibration weight manufacturer.

(iii) This paragraph (c)(3)(iii) shows an example of the buoyancy correction. This example assumes the following inputs: barometric pressure (P) = 101.325 kPa, temperature (T) = 22.0 °C, dewpoint temperature ( $T_{dp}$ ) = 9.5 °C, balance display (R) = 100.0000 mg, calibration weight density ( $\rho_w$ ) = 8,000 kg/m<sup>3</sup>, and filter material density ( $\rho_s$ ) = 2,300 kg/m<sup>3</sup>. Then: (A) The water vapor pressure ( $P_w$ ) is calculated as:  $P_w = 0.6113 \times 10^{((7.5 \times 9.5)/(237.3+9.5))} = 1.186$  kPa.

(B) The air density (A) is calculated as:  $A = (3.484 \times 101.325 - 1.317 \times 1.186)/(22.0+273.15) = 1.191$  kg/m<sup>3</sup>.

(C) The corrected mass (M) is calculated as:  $M = 100.0000 \times (1 - (1.191/8000))/(1 - (1.191/2300)) = 100.0369$  mg.

(4) The uncorrected weight, corrected weight, barometric pressure, temperature and humidity, of the filter shall be recorded. Afterward the filter shall be returned to the lower half of the filter cassette, and the upper half of the cassette shall be set in place. The cassette-with filter-shall then be stored in a covered glass petri dish or a sealed (i.e., ends plugged) filter holder assembly, either of which shall remain in the filter stabilization environment until needed for

testing. It is recommended that the filter be transported between the filter stabilization environment and the location of the emissions test within a sealed filter holder assembly.

(5) After the emissions test, the filter cassette shall be removed from the filter holder assembly. If this removal is performed in the filter stabilization environment, the upper half of the cassette shall be removed using a properly designed separator tool, the lower half of the cassette-with filter-shall be placed in a partially covered petri dish, and allowed to stabilize for at least 30 minutes (60 minutes for engines of model year earlier than 2007). Otherwise, the cassette and filter shall be placed in a closed petri dish until it can be returned to the filter stabilization environment. Once the closed petri dish is returned to the filter stabilization environment, the petri dish shall be opened, the upper half of the cassette shall be removed using a properly designed separator tool, the lower half of the cassette-with filter-shall be placed in a partially covered petri dish, and allowed to stabilize for at least 30 minutes (60 minutes for engines of model year earlier than 2007).

(6) After at least 30 minutes (60 minutes for engines of model year earlier than 2007), but no more than 60 hours of stabilization, each filter may be weighed using the specified microbalance. The process of weighing a filter may be repeated and a statistical mean may be calculated. Sound engineering judgment shall dictate the use of statistics to discard outliers and the weighting of averages. For a used filter, its single weight or statistical mean weight shall be identified as the uncorrected gross weight of the filter. The uncorrected gross weight shall be corrected for filter buoyancy using the procedure in (c) (3) of this section. The uncorrected gross filter weight, corrected gross filter weight, barometric pressure, temperature, and dewpoint shall be recorded.

(7) The net particulate matter weight (Pf) of each filter shall be equal to the corrected gross filter weight minus the corrected tare filter weight.

(8) Should the particulate matter on the filters contact the petri dish, tweezers, microbalance or any other surface, the data with respect to that filter is void.